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3.	Full name, address and postcode of the or of each applicant (*underline all surnames*)	KONINKLIJKE PHILIPS ELECTRONICS N.V. GROENEWOUDSEWEG 1 5621 BA EINDHOVEN THE NETHERLANDS
	Patents ADP Number (*if you know it*)	07419294001
	If the applicant is a corporate body, give the country/state of its incorporation	THE NETHERLANDS
4.	Title of the invention	RADIO COMMUNICATION SYSTEM, METHOD OF OPERATING A RADIO COMMUNICATION SYSTEM, AND A MOBILE STATION
5.	Name of your agent (*if you have one*)	
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DESCRIPTION

RADIO COMMUNICATION SYSTEM, METHOD OF OPERATING A RADIO COMMUNICATION SYSTEM, AND A MOBILE STATION

The invention relates to a radio communication system, a method of operating a radio communication system, and a mobile station for use in a radio communication system. While the present specification describes a system with particular reference to the Universal Mobile Telecommunication System (UMTS), the invention is also applicable to other mobile radio systems.

The current state of the art is described in the 3rd Generation Partnership Project (3GPP) specifications for UMTS which are available at http://www.3gpp.org .

When a mobile station (referred to in the UMTS specification as a User Equipment (UE)) is in soft handover, it receives power control commands from each of the base stations (referred to in the UMTS specification as Node Bs) with which it is connected (i.e. the base stations in the mobile station's active set). Each Base station generates power control commands for each mobile station according to whether the received Signal to Interference Ratio (SIR) from the mobile station is above or below a target level: a "down" command is transmitted to the mobile station if the received SIR is above the target and an "up" command if the received SIR is below the target. Consequently, in each timeslot a mobile station which is in soft handover may receive a variety of "up" and "down" commands from the different base stations in the active set. In each timeslot, the mobile station then combines these commands in order to make a decision as to whether to increase or decrease the uplink transmit power.

A flow diagram of the main specified requirements for this combining process for each time slot is shown in Figure 2. The definition of "reliable" and "unreliable" is not specified in the UMTS specifications. One way of operating

the mobile station is to compare the magnitude of the soft amplitude of each received Transmit Power Control (TPC) command against a pre-determined threshold, with TPC commands whose soft amplitude magnitude is greater than the threshold being considered to be reliable. Note that the reliability thresholds for "up" commands and "down" commands are not necessarily the same; one method of operation is to consider all commands which are not "reliably down" to be "reliably up".

In 3GPP Temporary Document R1-99j02, "Soft symbol reliability for uplink PC in soft handover (rev)" by Nokia (available at http://www.3gpp.org) the optimum position for this reliability threshold in certain conditions is identified.

An object of the invention is to provide improved power control during soft handover.

According to a first aspect of the present invention there is provided a mobile station for use in a radio communication system comprising a plurality of base stations, the mobile station comprising a receiver means for receiving signals including TPC commands from the plurality of base stations, measurement means for measuring a characteristic of the received signals and the amplitude of the received TPC commands relative to a reliability threshold, control means for deriving a control signal from the measurements, wherein the control means is adapted to vary the reliability threshold according to a function of the characteristic of the received signals, and a variable power transmitter means, wherein the variable transmitter power is responsive to the control signal.

The magnitude of the reliability threshold is adaptive according to a function of the characteristic of the received signals, such that the magnitude of the reliability threshold increases (thus rendering more commands "unreliable") for lower values of received SIR and decreases (thus rendering more commands "reliable") for higher values of received SIR.

According to a second aspect of the present invention there is provided a radio communication system comprising a plurality of base stations and at least one mobile station, each base station having a receiver means for receiving signals from the mobile station and a transmitter means for transmitting signals including TPC commands to the mobile station, and the mobile station having a receiver means for receiving the signals from the plurality of base stations, measurement means for measuring a characteristic of the received signals and the amplitude of the received TPC commands relative to a reliability threshold, control means for deriving a control signal from the measurements, wherein the control means is adapted to vary the reliability threshold according to a function of the characteristic of the received signals, and a variable power transmitter means, wherein the variable transmitter power is responsive to the control signal.

According to a third aspect of the present invention there is provided . method of operating a radio communication system comprising:

transmitting a signal from a mobile station;

receiving the signal at a plurality of base stations;

at each base station, in response to receiving the signal, deriving TPC commands and transmitting a signal comprising the TPC commands;

at the mobile station, receiving the TPC commands from the plurality of base stations;

measuring a characteristic of the received signals;

deriving a reliability threshold from the measurements of the characteristic;

measuring the soft amplitude of the received TPC commands relative to the reliability threshold;

deriving a control signal from the measurements of soft amplitude relative to the reliability threshold; and

adjusting the transmit power of the mobile station transmitter in response to the control signal.

The invention is based on the realisation that a pre-determined threshold position is not suitable for all conditions and that the optimum position of the reliability threshold is dependent on the received signal quality (e.g. SIR or average SIR) of the received TPC commands.

In one embodiment of the invention, the TPC bits may be transmitted at a higher power level than the accompanying data bits, although the power offset between the data bits and TPC bits is not known to the mobile station; in this case the magnitude of the reliability threshold may be set relative to the received amplitude of the data bits rather than the TPC or pilot bits. This ensures that the reliability threshold is not greater than the expected received amplitude of the TPC bits when the SIR is good, thus solving the problem that all TPC commands may be considered unreliable in the case when the mobile station does not know the value of the power offset between the data and the TPC bits.

A reliability threshold determined in accordance with the present invention will naturally adopt different values for the different base stations in the active set in each timeslot.

The invention will now be described, by way of example only, with reference to the accompanying drawings wherein;

Figure 1 is block schematic diagram of a radio communication system;

Figure 2 is a flow chart illustrating the basic requirements for combining power control commands in soft handover in UMTS;

Figure 3 is a graph showing the variation with time of the received signal to noise ratio of the power-controlled signal transmitted from the mobile station to three base stations in soft handover, after selection combining of the signals received by the three different base stations, when the mobile station uses a fixed reliability threshold of 0.25 for processing the TPC commands received from the base stations; three different values of Power Control Error Ratio (PCER) for the TPC commands transmitted by the base stations are illustrated.

Figure 4 is a graph showing the variation of signal to noise ratio with time after selection combining using a fixed threshold of 0.7 and two different values of PCER.

Figure 5 is a diagram illustrating the power offsets on downlink channels;

Figure 6 is a graph illustrating the performance when using an adaptive reliability threshold for PCER=4%; and

Figure 7 is a graph illustrating the performance when using an adaptive reliability threshold for PCER=25%.

Referring to Figure 1 there is shown a radio communication system 500 comprising a mobile station 100 and two base stations 200 coupled via a fixed network 400. The mobile station 100 may be, for example, a portable telephone, or a wireless Personal Digital Assistant (PDA), or any other type of wireless equipped electronic device. The radio system 500 may comprise a plurality of the mobile stations 100 and at least two of the base stations 200. The mobile station 100 comprises a transmitter means 110 and a receiver means 120. An output of the transmitter means 110 and an input of the receiver means 120 are coupled to an antenna 130 by a coupling means 140, which may be for example a circulator or a changeover switch. Coupled to the transmitter means 110 and receiver means 120 is a control means 150, which may be for example a processor. Each base station 200 comprises a transmitter means 210 and a receiver means 220. An output of the transmitter means 210 and an input of the receiver means 220 are coupled to an antenna 230 by a coupling means 240, which may be for example a circulator or a changeover switch. Coupled to the transmitter means 210 and receiver means 220 is a control means 250, which may be for example a processor. The control means 250 is coupled to the fixed network 400. Transmission from the mobile station 100 to each base station 200 takes place on an uplink frequency channel 160 and transmission from the base stations 200 to the mobile station 100 takes place on a downlink frequency channel 260. In the

following description it is assumed that the transmissions use spread spectrum techniques such that signals are spread using a spreading code, and data and control signals may be transmitted simultaneously with different spreading codes. However, such an assumption is not essential to the invention.

In operation, when the mobile station 100 is in soft handover, it can communicate with a plurality of base stations 200. The set of base stations 200 with which the mobile station 100 can communicate is termed the active set. The mobile station 100 transmits from its control means 150 via the transmitter means 110 a control signal to the active set of base stations 200. Each base station 200 receives the control signal via its receiver means 220. At each base station, the control means 250 determines whether the Signal to Interference Ratio (SIR) of the received control signal is above or below a target level, and issues a TPC command which is transmitted to the mobile station 100 by the base station transmitter means 220. A “down” command is transmitted to the mobile station 100 if the received SIR is above the target and an “up” command if the received SIR is below the target. Consequently, in each timeslot a mobile station 100 which is in soft handover may receive via the receiver means 110 a variety of “up” and “down” commands from the different base stations 200 in the active set. In each timeslot, the control means 150 of the mobile station 100 then combines these commands in order to make a decision as to whether to increase or decrease the uplink transmit power, and then generates a control signal which is used by the transmitter means 110 to adjust the transmit power according to the decision.

In order to make the decision, the reliability of each received TPC command is taken into account; the control means 150 includes a measurement means for measuring the soft amplitude of each TPC command which it then compares against a reliability threshold, with TPC commands whose soft amplitude magnitude is greater than the threshold being considered to be reliable.

In the conditions where the SIR is relatively high, the optimal reliability threshold position is low, for example 0.25 relative to the expected received

amplitude of the TPC commands. This results in most of the TPC commands being considered to be reliable.

In the conditions where the SIR is relatively poor, a much higher reliability threshold position is needed, for example 0.7 in order to avoid instability arising from the requirement shown in Figure 2 for the mobile station to reduce its transmitted power if any one of the TPC commands in the current slot are reliably "down". In particular, if the received uplink SIR at all the base stations 200 in the active set is below their SIR targets, such that all base stations 200 in the active set transmit "up" commands, the poor SIR of the TPC commands will result in a high probability that at least one of the "up" commands will be received erroneously by the mobile station as a reliable "down" command, especially if the magnitude of the reliability threshold is low. Consequently, the transmitter means 110 of the mobile station 100 will continue to reduce its uplink transmit power, even though all the base stations 200 in the active set are requesting a power increase. This is illustrated in Figure 3, which shows the received uplink E_b/N_0 after selection combining between three base stations 200 in the active set, and with a static reliability threshold of 0.25. The Power Control Error Ratio (PCER) is a measure of the SIR of the TPC commands, and is defined as the proportion of TPC commands received as "up" when "down" was transmitted and vice versa, if a hard decision is taken against a zero threshold. Typical PCERs are generally considered to be in the range 4 to 10%, although this range could be as high as 30% in some situations in soft handover.

Note that for higher values of PCER, the transmit power of the mobile station 100 falls extremely rapidly (although in practice the depth of the fades would be limited by the dynamic range of the transmit power of the mobile station's transmitter 120).

This behaviour is highly undesirable, as the connection between the mobile station 100 and a base station 200 will be dropped as the uplink transmit power decreases, and this will become more likely the more base stations 200 there are in the active set.

The improvement resulting from using a higher reliability threshold of 0.7 in conditions where the SIR is relatively poor is illustrated in Figure 4, where it can be seen that the variability of the received SIR is much reduced relative to the variability exhibited in Figure 3.

A single static value of the reliability threshold cannot give good performance in all conditions, and therefore in accordance with the invention the reliability threshold is adapted by the control means 150 according to a function of the SIR of the received TPC commands. The SIR of the received TPC commands is measured by the measurement means of the control means 150.

A further problem with the current state of the art is that the mobile station 100 is not told in UMTS what transmit power offset is currently being used for the downlink TPC commands relative to the downlink pilot bits. The downlink TPC commands are transmitted at a power offset PO2 relative to the Downlink Dedicated Physical Data Channel (DPDCH). The other downlink control fields, Pilot and TFCI (Transport Format Combination Indicator), are transmitted at power offsets PO3 and PO1 respectively relative to the DPDCH, as illustrated in Figure 5. Each of PO1, PO2 and PO3 may take any value between 0dB and +6dB in 0.25dB increments and may vary during a connection. However, only PO3 is signalled to the mobile station 100. This limits the mobile station's ability to position the reliability threshold in a suitable place.

In one embodiment of the invention, the reliability threshold is determined as

$$r_i' = d_i\left(1 - \frac{c}{c+s}(1-r)\right) \quad (1)$$

where:

r_i' is the magnitude of the reliability threshold for the i^{th} base station 200 in the active set;

d_i is the expected received amplitude of the data bits from the i^{th} base station 200, which may be derived from the measured pilot amplitude minus the power offset PO3;

s is a function of the inverse of the SIR on the received TPC commands, such as $s = \frac{\text{Noise power}}{\text{Signal voltage}}$ or $s = \frac{1}{\text{SIR}}$;

c is an arbitrary constant; and

r a constant representing the minimum magnitude of the reliability threshold.

The presence of c in the denominator of equation (1) prevents the magnitude of the reliability threshold from ever becoming zero or negative. The signal voltage, noise power and/or SIR are estimated by the measurement means, for example from the received amplitudes of the TPC field, pilot field and/or data fields.

Various measures of the effectiveness of such an embodiment may be used. One such measure is the standard deviation of the resulting uplink E_b/N_0 after selection combining of the signals received by the various base stations 200 in the active set. Another such measure is the uplink E_b/N_0 required after selection combining in order to give a target Quality of Service (QoS), such as Bit Error Ratio (BER).

Figures 6 and 7 show that the present invention is highly effective in a wide range of situations. Figure 6 shows that when the PCER = 4% an adaptive reliability threshold can give performance (in terms of SIR standard deviation) as good as a low static reliability threshold. Figure 7 shows that the same adaptive threshold formula gives performance as good as a high static reliability threshold when the PCER is much worse (25%).

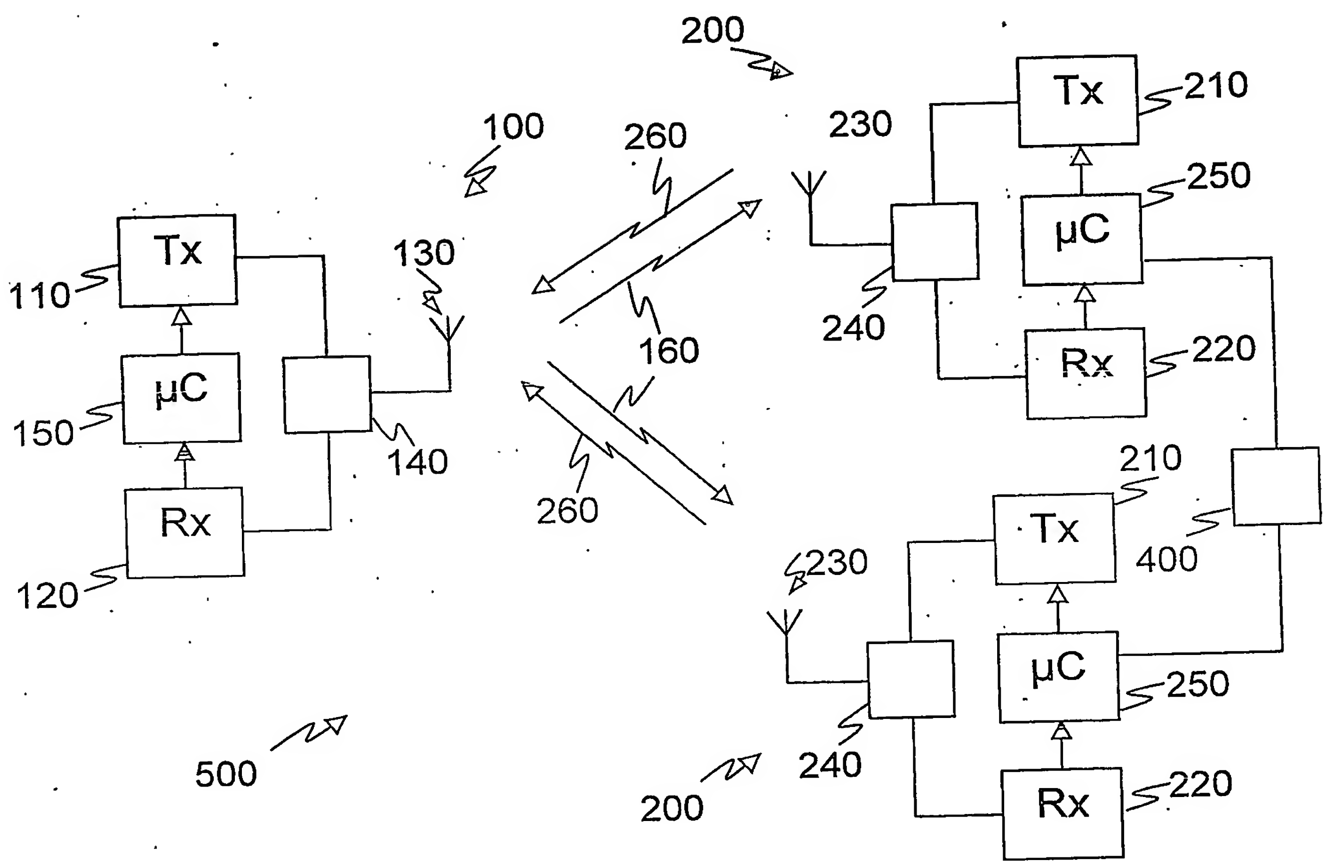
Embodiments of the present invention have been described using spread spectrum Code Division Multiple Access (CDMA) techniques, as used for example in UMTS. However, the invention is not limited to use in CDMA systems. Similarly, although embodiments of the present invention have been described assuming frequency division duplex, the invention is not limited to

use in such systems. It may also be applied to other duplex methods, for example time division duplex.

The functionality of the base station 100 may be distributed across a variety of fixed parts of a communications network. In this specification, the use of the term ``base station" is therefore to be understood to include those parts of a communication network involved in an embodiment of the present invention.

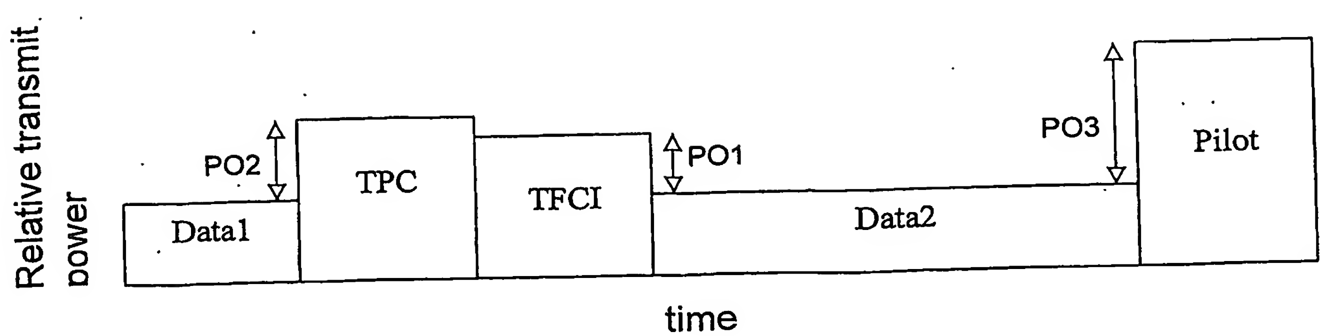
From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in radio communication systems and component parts thereof, and which may be used instead of or in addition to features already described herein.

In the present specification and claims the word “a” or “an” preceding an element does not exclude the presence of a plurality of such elements. Further, the word “comprising” does not exclude the presence of other elements or steps than those listed.



200
100
260
230
Tx
210
250
µC
130
110
150
µC
160
240
Rx
220
140
Rx
120
260
210
Tx
400
230
µC
250
500
240
200
Rx
220

Fig. 1



Relative transmit power
PO2
TPC
TFCI
PO1
PO3
Pilot
Data1
Data2
time

Fig. 5

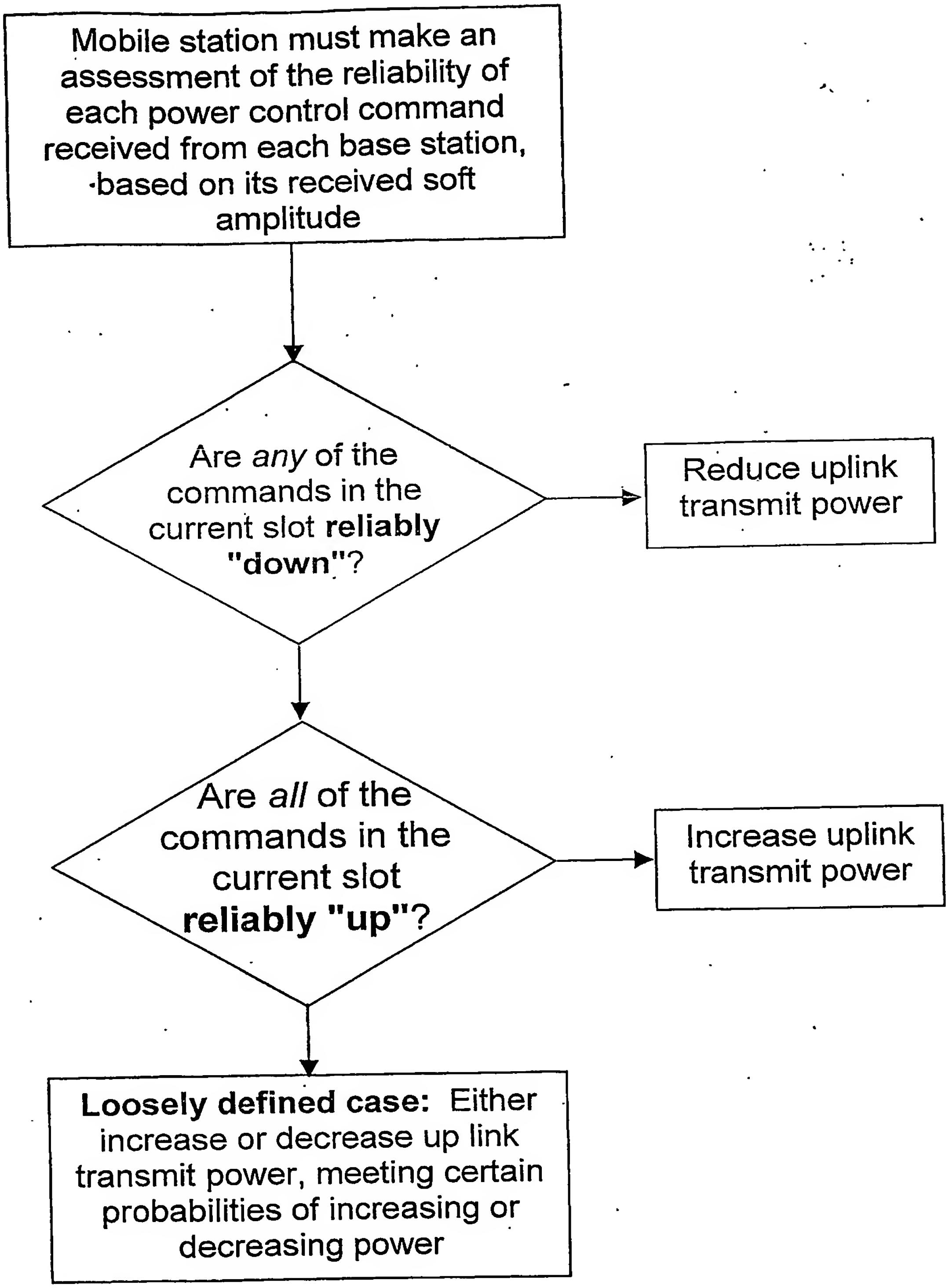

Mobile station must make an assessment of the reliability of each power control command received from each base station, based on its received soft amplitude
Are *any* of the commands in the current slot **reliably "down"**?
Reduce uplink transmit power
Are *all* of the commands in the current slot **reliably "up"**?
Increase uplink transmit power
Loosely defined case: Either increase or decrease up link transmit power, meeting certain probabilities of increasing or decreasing power

Fig. 2

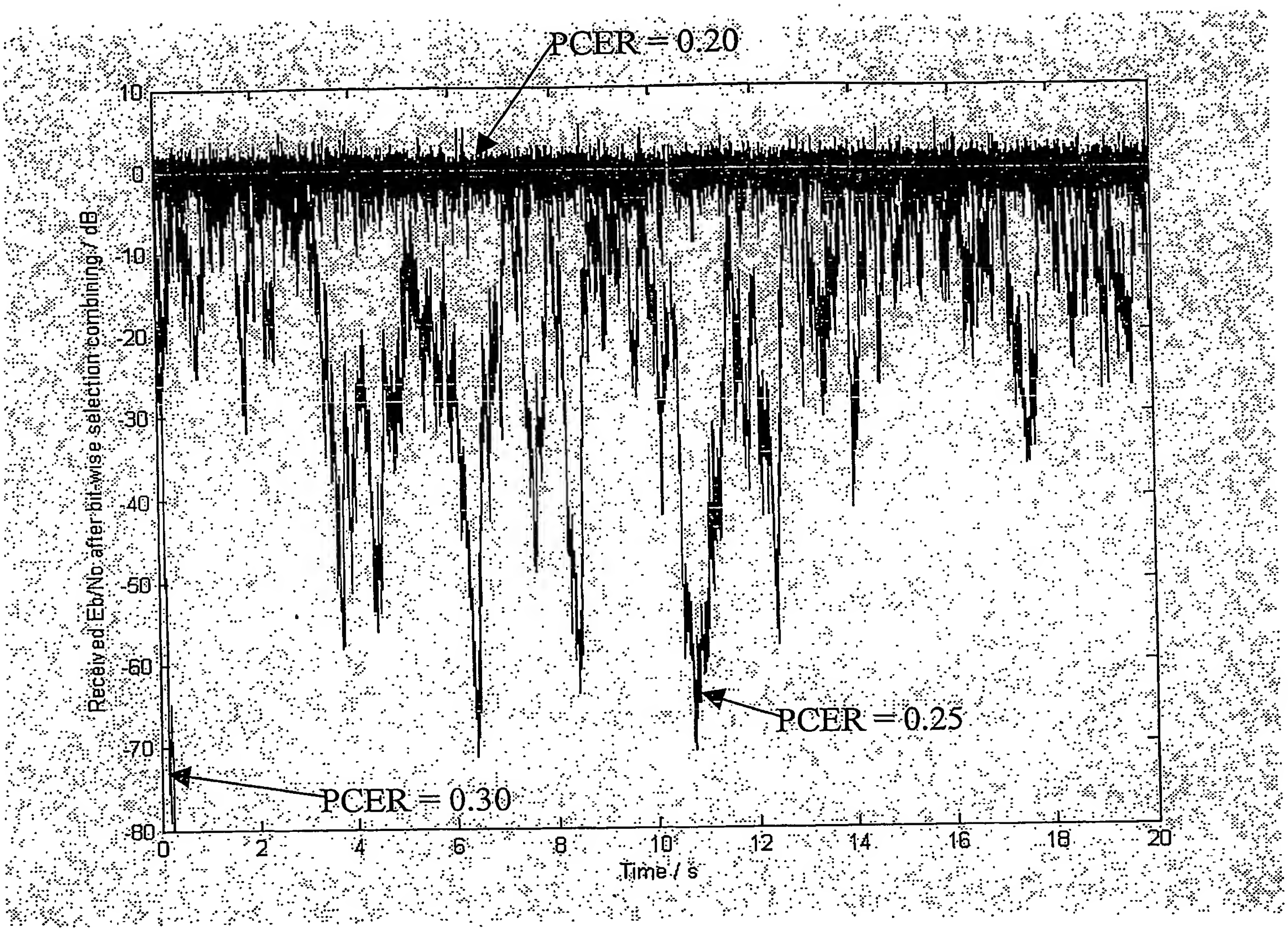

PCER = 0.20
PCER = 0.25
PCER = 0.30
Received Eb/No after bit-wise selection combining / dB
Time / s
10
0
-10
-20
-30
-40
-50
-60
-70
-80
0
2
4
6
8
10
12
14
16
18
20

Fig. 3

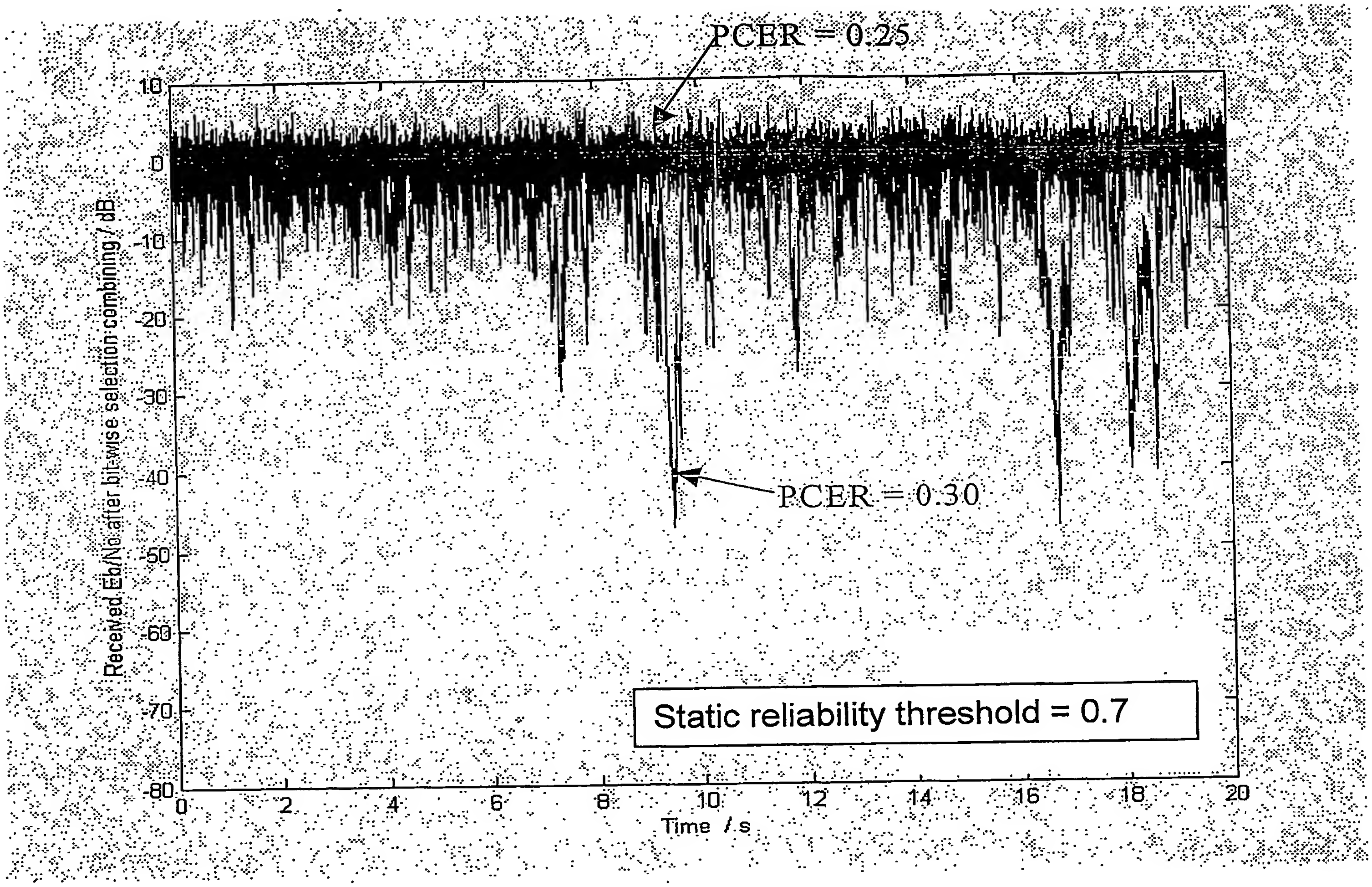


Fig. 4

PHGB030103GBQ

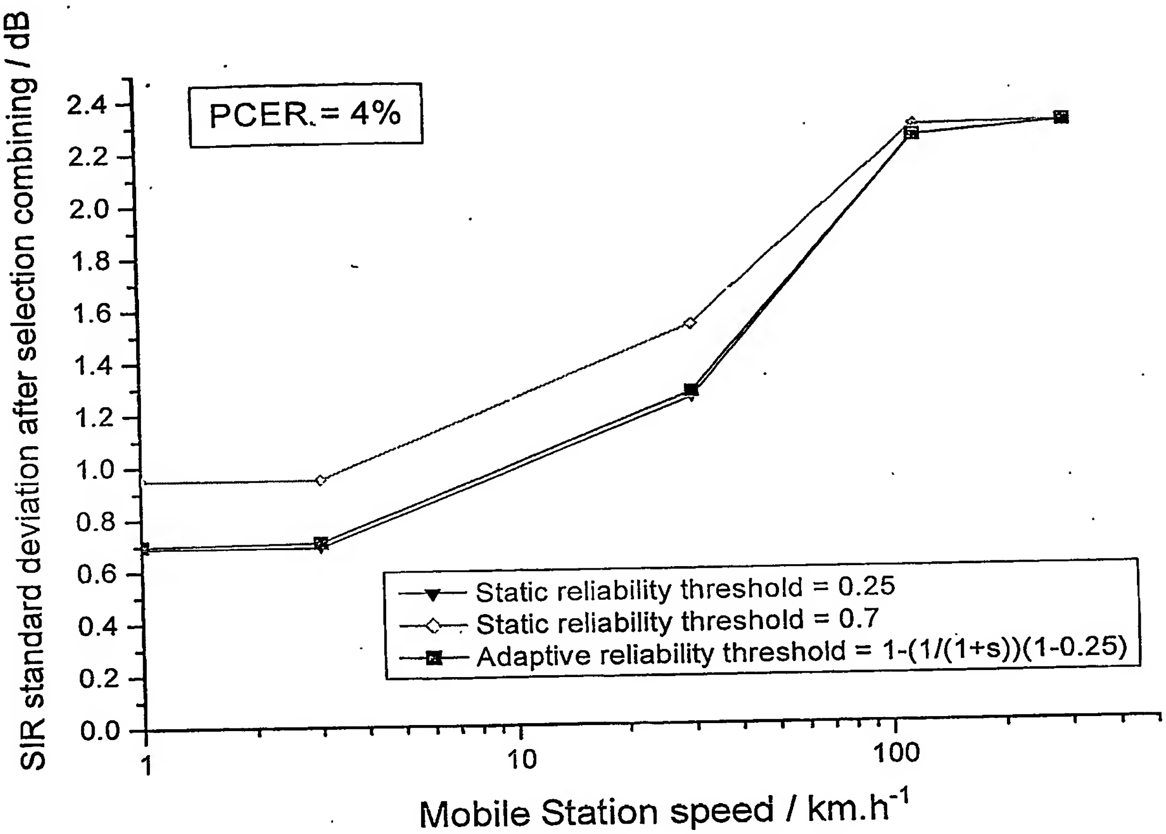
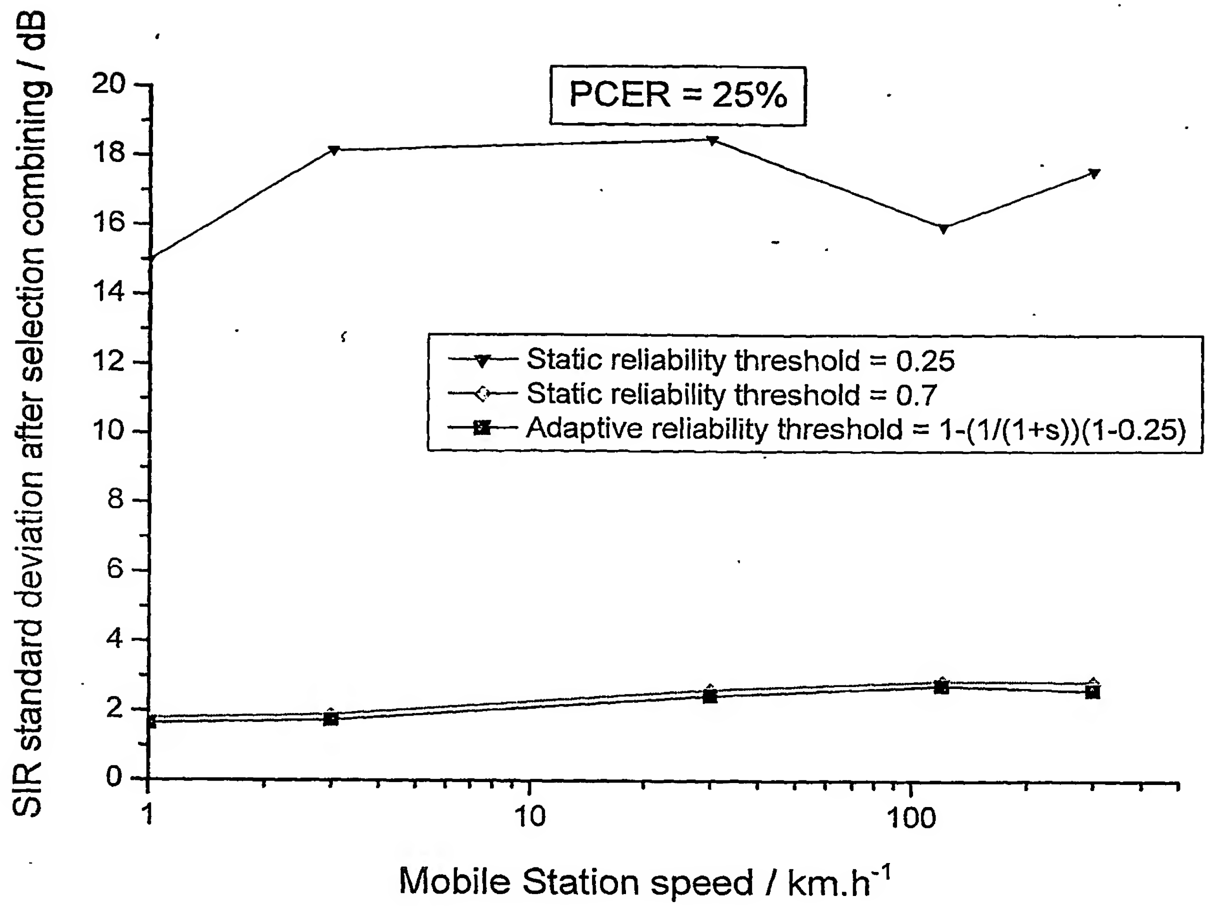

SIR standard deviation after selection combining / dB
PCER = 4%
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Static reliability threshold = 0.25
Static reliability threshold = 0.7
Adaptive reliability threshold = 1-(1/(1+s))(1-0.25)
1
10
100
Mobile Station speed / km.h-1

Fig. 6



PCER = 25%
SIR standard deviation after selection combining / dB
20
18
16
14
12
10
8
6
4
2
0
Static reliability threshold = 0.25
Static reliability threshold = 0.7
Adaptive reliability threshold = 1-(1/(1+s))(1-0.25)
1
10
100
Mobile Station speed / km.h-1

Fig. 7